A VIRTUAL PETROLOGICAL MICROSCOPE FOR ALL APOLLO 11 LUNAR SAMPLES.

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Abstract: A means of viewing, over the Internet, polished thin sections of every rock in the Apollo lunar sample collections *via* software, duplicaing many of the functions of a petrological microscope, is described.

Introduction: During the six NASA missions to the Moon from 1969-72 a total of 382kg of rocks and soils, often referred to as "the legacy of Apollo", were collected and returned to Earth. A unique collection of polished thin sections (PTSs) was made from over 400 rocks by the Lunar Sample Curatorial Facility at the Johnson Spacecraft Center (JSC), Houston. These materials have been available for loan to approved PIs but of course they can't be simultaneously investigated by several researchers unless they are co-located or the sample is passed back and forward between them by mail/hand carrying which is inefficient and very risky for irreplaceable material.

When The Open University (OU) the world's largest Distance Learning Higher Education Establishment found itself facing a comparable problem (how to supply thousands of undergraduate students with an interactive petrological microscope and a personal set of thin sections) it decided to develop a software tool called the Virtual Microscope (VM) [1]. As a result it is now able to make the unique and precious collection of Apollo specimens universally available as a resource for concurrent study by anybody in the world's Earth and Planetary Sciences community. Herein we describe the first steps of a collaborative project between OU and the JSC Curatorial Facility to record a PTS for every lunar rock beginning with those collected by the Apollo 11 mission.

Method: Production of a virtual microscope dedicated to a particular theme divides into four main parts - photography, image processing, building and assembly of virtual microscope components, and publication on either a website and/or in the form of an iBook.

Two large research quality microscopes are used to collect all the images required for a virtual microscope. The first is part of an integrated package that utilises PowerMosaic software and a motorised XYZ stage to generate large area mosaics. It includes a fast acquisition camera and depending on the PTS size normally is used to produce seamless mosaic images consisting of 100-500 individual photographs. If the sample is suitable, three mosaics of each sample are recorded - plane polarised light, between crossed polars and reflected light. In order for the VM to be a true petrological microscope it is necessary to recreate the features of a rotating stage and perform observations using filters to produce polarised light. Thus the petrological VM includes the capability of seeing changes in optical properties (pleochroism and birefringence) during rotation allowing mineral identification.The second microscope in the system provides the functions of the rotating stage (Figure 1). To this microscope we have added a robotically controlled motor to acquire seventy-two images (5° intervals) in plane polarised light and between crossed polars.

To process the images acquired from the two microscopes involves a combination of proprietary software (Photoshop) and our own in-house code.

The final stage involves assembling all the components in an HTML5 environment. For interactive books (iBooks) this means building 'widgets' that can then be dropped into the books.

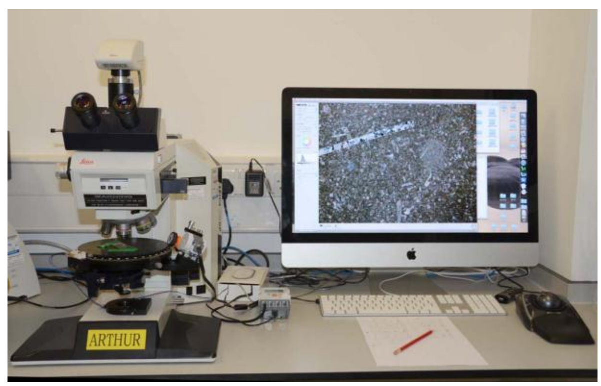

Figure 1: Rotating stage microscope with Mindstorm motor

Pathfinder investigations: We have undertaken a number of pilot studies to demonstrate the efficacy of the petrological microscope with lunar samples. The first was to make available on-line images collected from the package of Apollo samples provided by NASA to the UK STFC (Science and Technical Facilities Council) for loan as educational material e.g. for schools. The real PTSs of the samples are now no longer sent out to schools removing the risks associated with transport, accidental breakage and eliminating the possibility of loss.

The availability of lunar sample VM-related material was further extended to include twenty-eight specimens

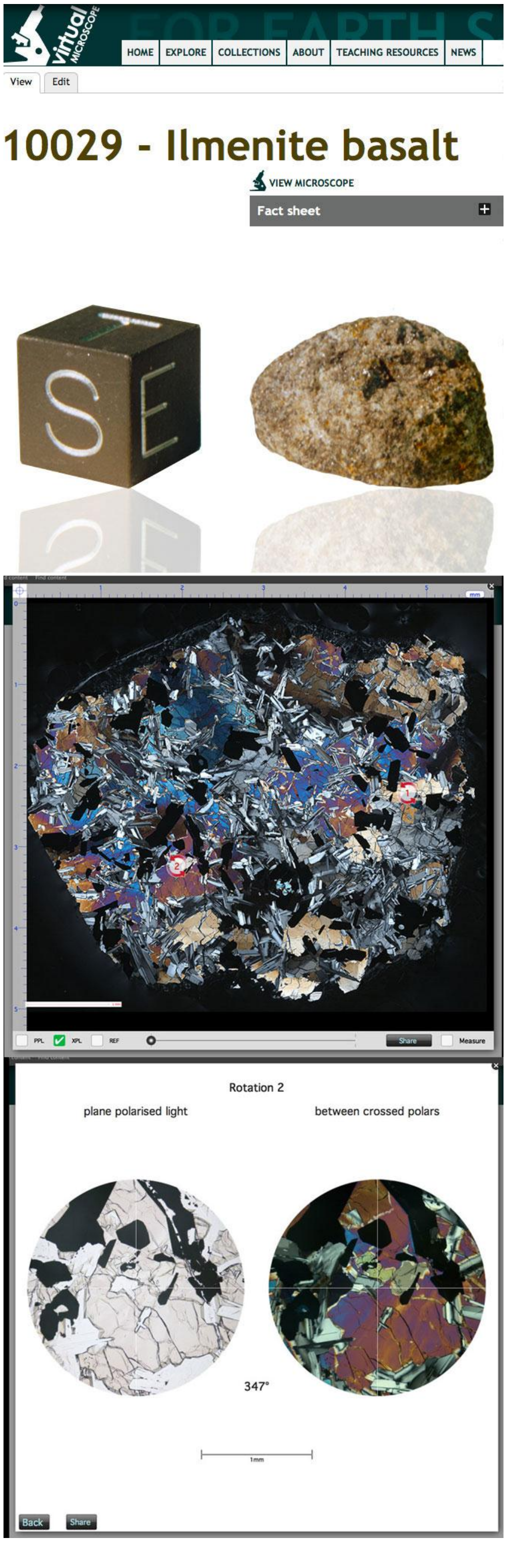

Figure 2 Screen shots from the A11 virtual microscope.

from all of the Apollo missions and made more generally available through an ibook entitled "Moon Rocks: an introduction to the Geology of the Moon" free from the Apple Bookstore **[1]**.

The current appetite of the worldwide public for infomaion and knowledge concerning the Moon has been demonstrated through a trial website: http://www.open.ac.uk/earthresearch/tindle/AGT/AGT_Home_2010/Virtual_Microscope-UserMap.html which has received hits from every continent and over a hundred countries including some anticipated sources e.g. from meteorite hunters on Antarctica but also from some unexpected locations: for example Mongolia.

Research possibilities: Although the Virtual Microscope was originally conceived as a teaching aid and was later recognised as a means of public outreach and engagement, we now realise that it also has enormous potential as a high level research tool.

Following discussions with Gary Lofgren and Carl Allen at JSC we have received CAPTAN permission to embark on a programme of digitizing the entire lunar sample PTS collection for all three of the above purposes. By the time of the 45th LPSC we will have completed forty-two rocks collected during the Apollo 11 mission and the data, cross-links to Lunar Sample Compendium [2] will go live on the Web immediately following its presentation.

The lunar sample VM will enable large numbers of skilled/unskilled microscopists (professional and amateur researchers, educators and students, enthusiasts and the simply curious non-scientists) to share the information from a single sample. It will mean that all the PTSs already cut, even historical ones, could be available for new joint investigations or private study. The scientific return from the collection will increase exponentially as a result of further debate and discussion..

Simultaneously the VM will remove the need for making unnecessary multiple samplings, avoid consignment of delicate/breakable specimens (all of which are priceless) to insecure mail/courier services and reduce direct labour and indirect costs, travel budgets and unproductive travelling time necessary for co-location of collaborating researchers.

For the future we have already recognized further potential for virtual technology. There is nothing that a petrologist likes more than to see the original rock as a hand specimen. It is entirely possible to recreate virtual hand specimens with 3-D hard and software, already developed for viewing fossils, located within the Curatorial Facility.

References:

[1] Tindle, A.G. and Kelley, S.P. (2012). *Moon Rocks: An Introduction to the Geology of the Moon.* Open University.

[2] http://curator.jsc.nasa.gov/lunar/lsc/index.cfm